The ICD, a first step towards the Intensity Frontier

We have developed an initial configuration for the Steering Group path to the intensity frontier. It consists of an 8 GeV superconducting linac, the Recycler, and the Main Injector. I will describe the configuration, the reasoning, and the first thoughts on the plan

Paul Derwent

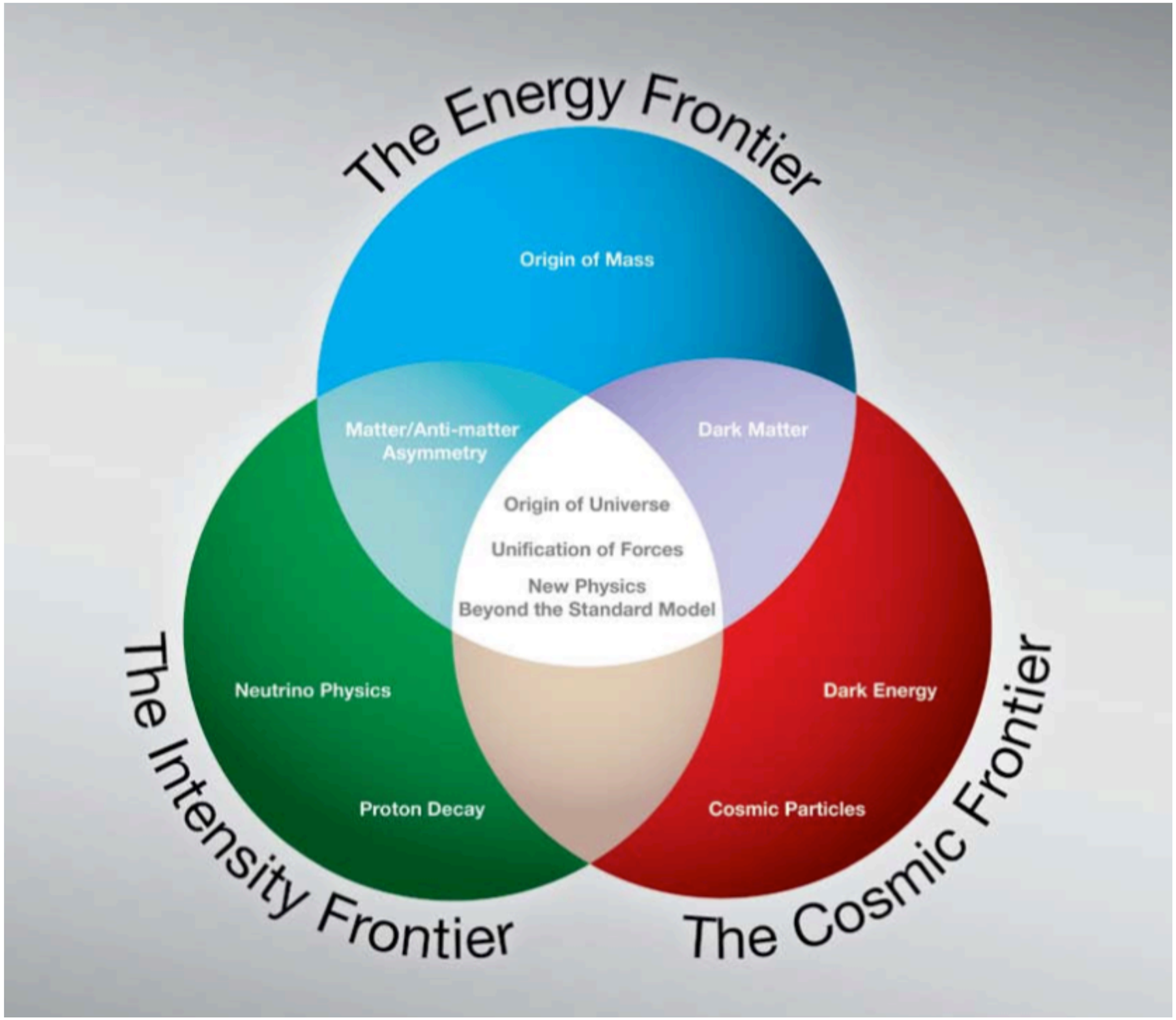
AP&T Seminar

30 Oct 08

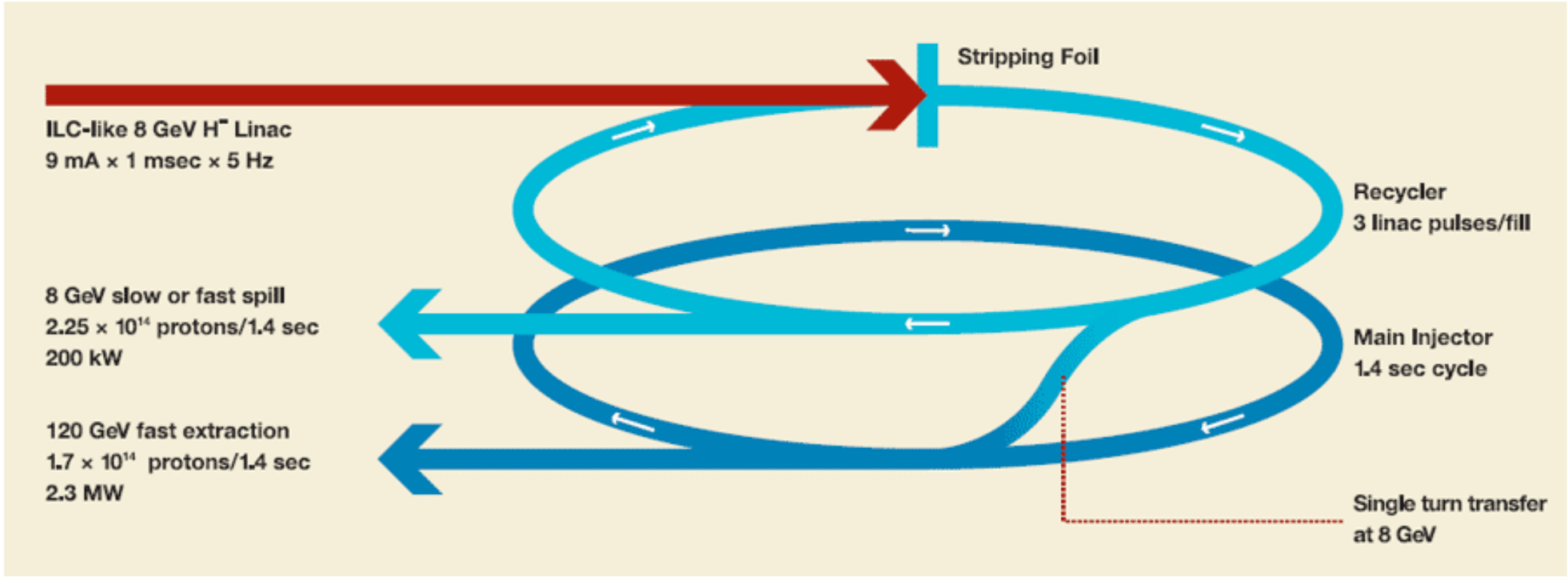
An ICD?

- What is an ICD?
  - Initial Configuration Document
- What is its role?
  - Projects have to work within context of DoE order 413.3a (a 54 page document)
    - Program and Project Management for the acquisition of Capital Assets
    - Critical Decision path
  - Input to CD-0 "Approve Mission Need"
    - R&D and Conceptual Planning
    - "A Mission Need Statement is the translation of this gap into functional requirements that cannot be met through other than material means. It should describe the general parameters of the project, how it fits within the mission of the Program, and why it is critical to the overall accomplishment of the Department mission, including the benefits to be realized. **The mission need is independent of a particular solution, and should not be defined by equipment, facility, technological solution, or physical end-item.** This approach allows the Program the flexibility to explore a variety of solutions and not limit potential solutions."
  - but we also need a cost estimate!!!!! so we need a configuration to cost

The Intensity Frontier



- "a plan to keep U.S. accelerator based particle physics on the pathway to discovery … in the domain of neutrinos and precision physics with a high intensity accelerator"
- if the ILC stays on GDE's technically driven timeline
  - NOvA using the Recycler/MI to reach 700 kW at 120 GeV
- if ILC construction must wait somewhat longer
  - SNuMI using the Accumulator/Recycler/MI to reach 1.2 MW at 120 GeV
- if the ILC start is postponed significantly
  - Project X, a linac with the "currently planned characteristics of the ILC" combined with the Recycler/MI to reach 2.3 MW at 120 GeV



The Intensity Frontier -- the P5 report June 2008

- What is the intensity frontier?
  - "using intense beams to uncover the elusive properties of neutrinos and observe rare processes that probe physics beyond the Standard Model"

- How do we get there?
  - "The US can build on the unique capabilities and infrastructure at Fermilab and the proposed DUSEL, the deep underground science and engineering laboratory proposed for the Homestake Mine, to develop a world-leading program in neutrino science. Such a program will require a multi-megawatt proton source at Fermilab"

- What are the recommendations?
  - "The panel recommends a world-class neutrino program as a core component of the US program, with the long-term vision of a large detector in the proposed DUSEL laboratory and a high-intensity neutrino source at Fermilab."
  - "The panel recommends pursuing the muon-to-electron conversion experiment, subject to approval by the Fermilab PAC, under all budget scenarios considered by the panel."
  - "The panel recommends proceeding now with an R&D program to design a multi-megawatt proton source at Fermilab and a neutrino beamline to DUSEL and recommends carrying out R&D on the technology for a large multi-purpose neutrino and proton decay detector."

Development of the configuration

- Steering Group Report
  - "a linear accelerator with the currently planned characteristics of the ILC combined with Fermilab's existing Recycler Ring and Main Injector accelerator"
  - "the same as or similar to those used in the ILC at a scale of about 1% of a full ILC linac"

- 8 GeV H^- linac
  - 9 mA x 1 msec x 5 Hz ⇒ 5.6 x 10^{13} particles per pulse
  - Strip and accumulate 3 pulses in Recycler
  - transfer to Main Injector

- Emphasis on synergy with ILC:
  - scale test
  - industrialization
  - ⇒ 9 mA x 1 msec x 5 Hz

- Jan - May 08
  - R&D plan to develop concepts towards CD-2

- May 08 AAC
  - "Project-X, based on a superconducting linac, is important but aside from synergy with ILC, hard to justify unless one thinks of the long-term goals of Project-X – what upgrade potential could be incorporated from the start that would demand a superconducting linac?"
  - June 08 P5 Report

Development of the configuration

- Summer 2008:
  - not to emphasize ILC alignment --
    - "not to compromise Project X for ILC alignment"
  - build the linac that best suits the current and future needs
    - beam to the Main Injector
    - beam to other programs
  - August 2008 working group to revise the configuration of the project
  - are there other ways? talk about where this fits later....
    - cw linac?
    - linac + synchrotron?
- Meet the three objectives presented in the P5 report

The Intensity Frontier -- the P5 Report

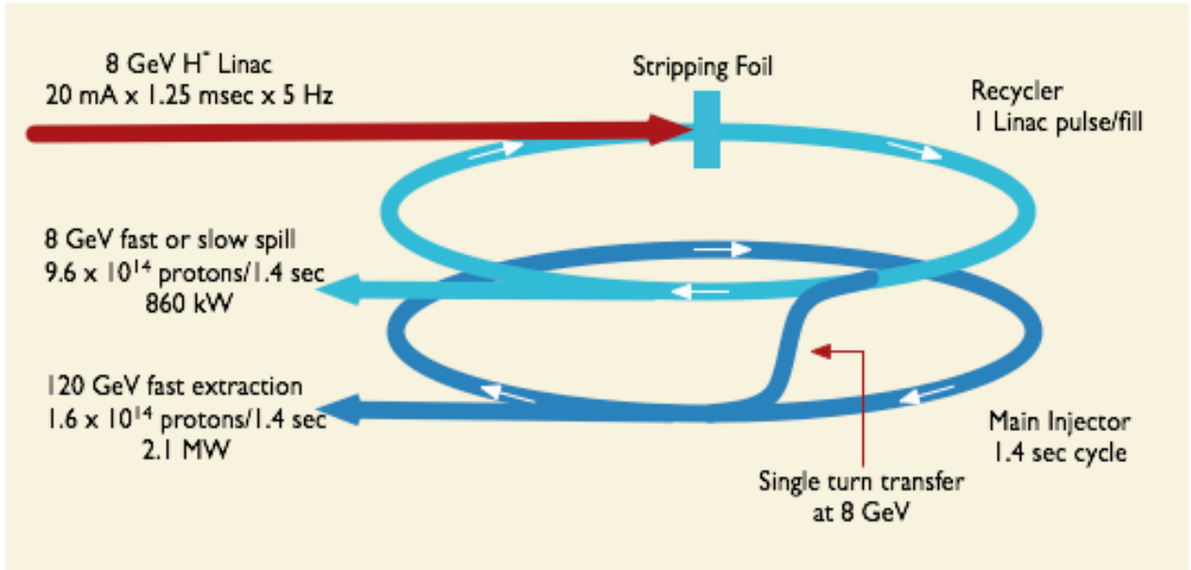
- **P5 report:** Fermilab's physics vision for this proton source has three main elements:

  1. *A neutrino beam for long baseline neutrino oscillation experiments.* A new 2-megawatt proton source with proton energies between 50 and 120 GeV would produce intense neutrino beams, directed toward a large detector located in a distant underground laboratory.

  2. *Kaon-and muon-based precision experiments exploiting 8 GeV protons from Fermilab's Recycler, running simultaneously with the neutrino program.* These could include a world-leading muon-to-electron conversion experiment and world-leading rare kaon decay experiments.

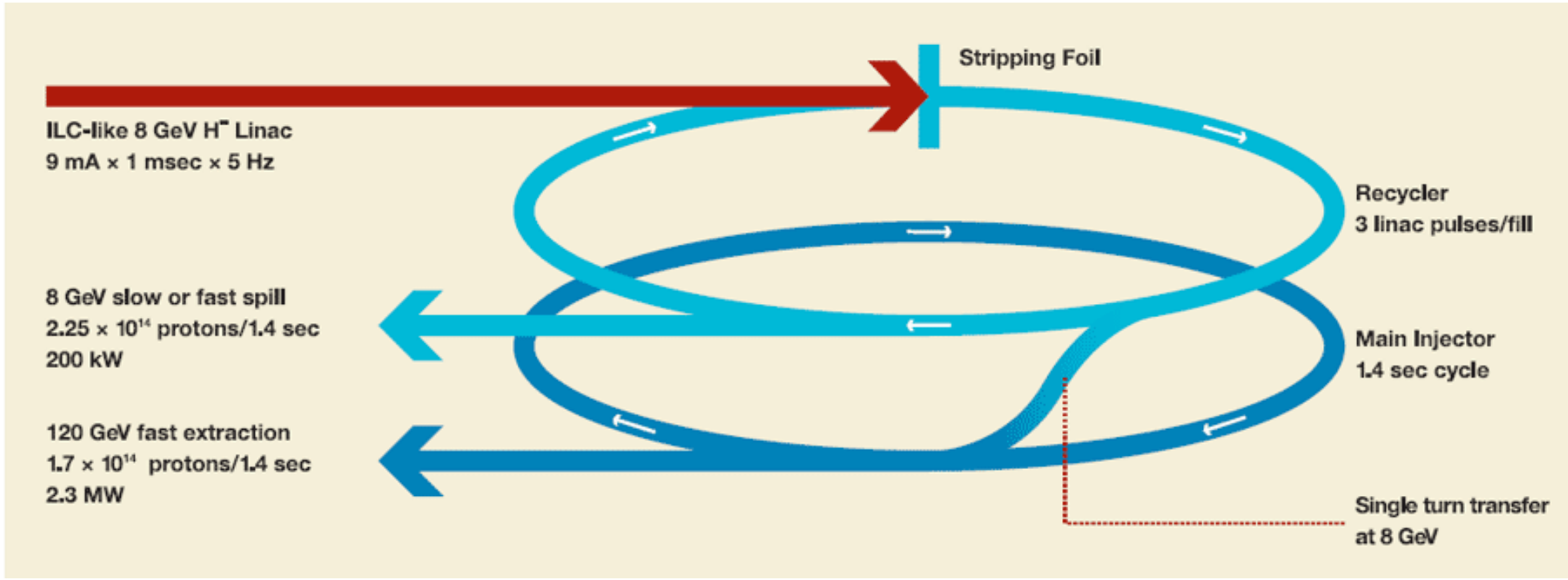
  3. *A path toward a muon source for a possible future neutrino factory, and, potentially, a muon collider at the Energy Frontier.* This path requires that the new 8 GeV proton source have significant upgrade potential.

These physics objectives define the mission need.



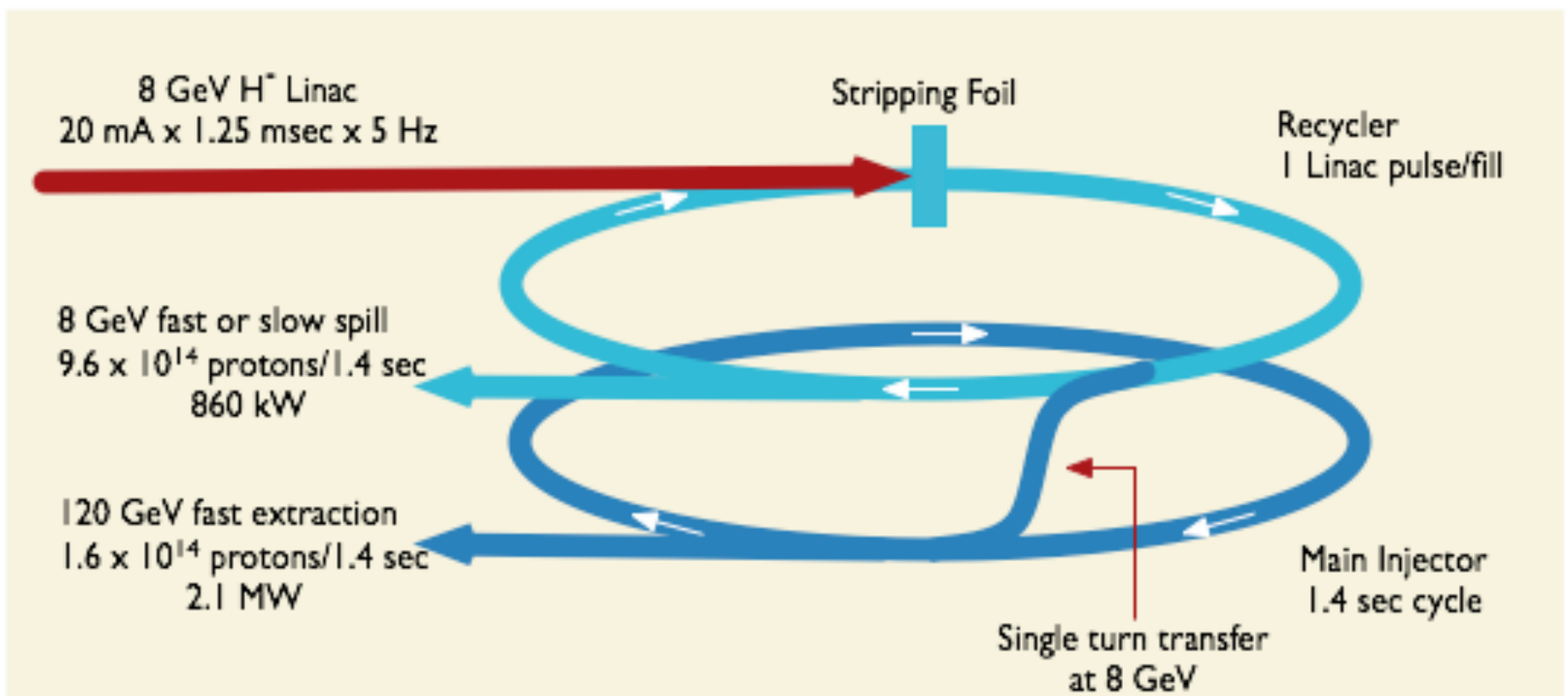
- **#1**
  - 1.6e14 / 1.4 sec at 120 GeV: 2.1 MW
    - 20 mA, 1.25 msec, 5 Hz from 8 GeV H^- linac
    - Strip in Recycler
    - Single Turn transfer to MI
- **#2**
  - 3 pings from Recycler to Accumulator
    - 7e13 / 1.4 (0.7) sec at 8 GeV: 70 (140) kW for mu2e
    - >3(6)× improvement over NOvA era beam power
  - Investigate slow spill
- **#3**
  - upgrade path to 10 Hz, longer pulse length

Comparison

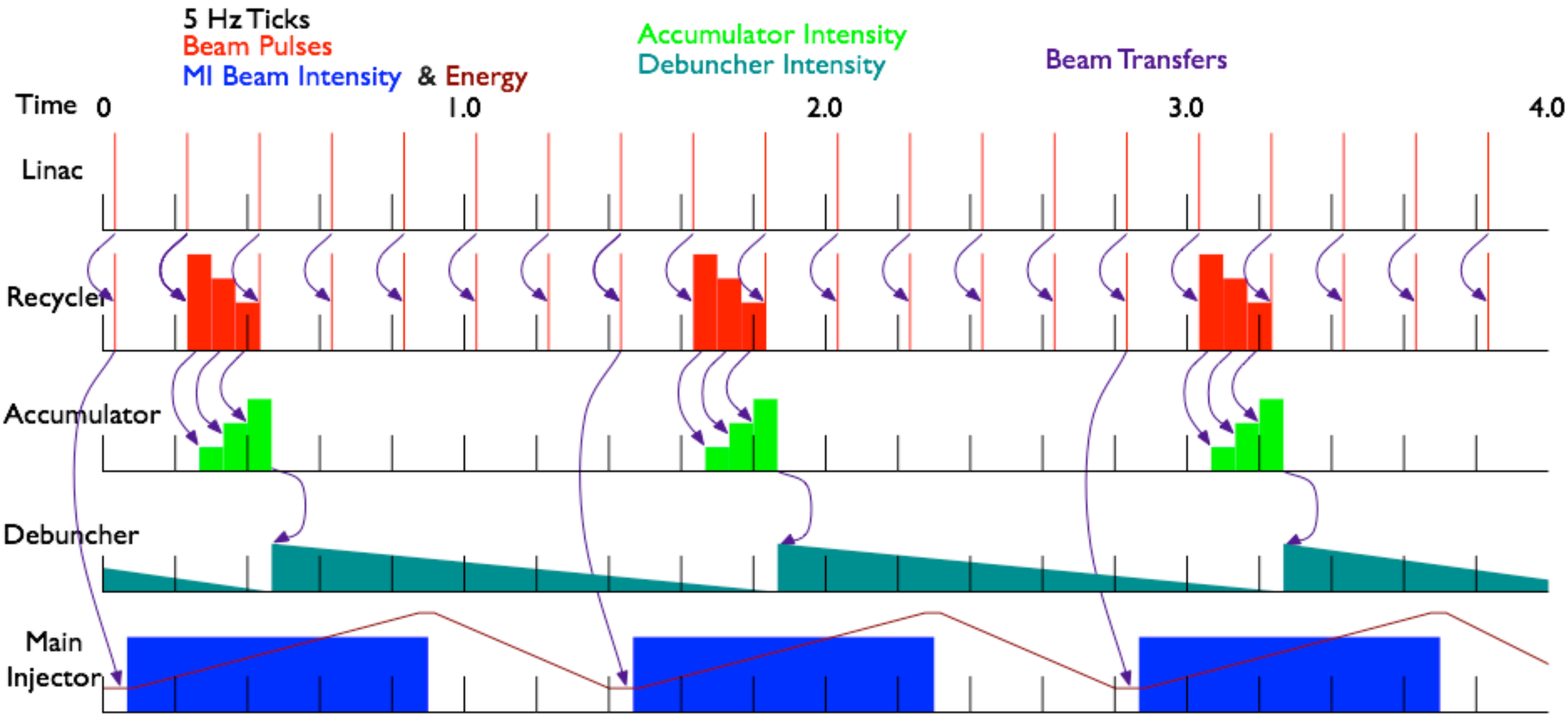


Steering Group
Project X

Initial
Configuration
Document



Operational Scenario



1.6e14 per pulse from Linac (5 Hz)
1.6e14 through Recycler to Main Injector (every 1.4 sec)
8e13 through Recycler to Accumulator (every 1.4 sec)

8e13 through Accumulator to Debuncher (every 1.4 sec)
7 Linac Cycles per MI Cycle: 1 to MI, 1 to mu2e,
5 available for diagnostics/commissioning/future experiments

Technical Goals

Linac		
	Particle Type	H-
	Beam Kinetic Energy	8 GeV
	Particles per pulse	1.6×10^{14}
	Pulse Rate	5 Hz
	Beam Power	1 MW
	Average Pulse Beam Current	20 mA
	Beam Pulse Length	1.25 msec
Recycler		
	Particle Type	proton
	Beam Kinetic Energy	8 GeV
	Cycle Time	0.2 sec
	Particles per cycle to MI	1.6×10^{14}
	Beam Power to MI	143 kW
	Additional Beam Power available	857 kW
Main Injector		
	Particle Type	proton
	Beam Kinetic Energy (maximum)	120 GeV
	Cycle Time	1.4 sec
	Particles per cycle from MI	1.6×10^{14}
	Beam Power at 120 GeV	2.1 MW

Initial Configuration Parameters

http://pfdpro.fnal.gov/ICD/ICD%20Requirements.xls

Req. No.	Description	Req.	Unit	Reference Requirements			
1.0	General						
1.1	120 GeV Beam Power	2.1	MW				
1.2	Total Linac Beam Power	1.0	MW				
1.3	Available (outside of MI) Linac Beam Power	0.9	MW				
1.4	Available (outside of MI) Duty Factor	86	%				
1.5	120 GeV Availability	75	%				
1.6	8 GeV Availability	80	%				
2.0	325 MHz Linac						
2.1	Average Beam Current	20	mA	1.2			
2.2	Pulse Length	1.25	msec	1.2			
2.3	Repetition rate	5	Hz	1.2			
2.4	325 MHz Availability	98	%	1.6			
2.5	Peak RF Current	31.9	mA	2.1	2.11	2.13	2.14
2.6	Final Energy	420	MeV	3.7			
2.7	Energy Variation (rms)	1	%	3.11			
2.8	Bunch Phase jitter (rms)	1	degree	3.12			
2.9	Linac Species	H-		4.1			
2.10	Transverse Emittance (95% normalized)	2.5	π-mm-mrad	5.7	5.8		
2.11	Macro Bunch Duty Factor	67	%	5.10	5.12		
2.12	Macro Bunch Frequency	53	MHz	5.12			
2.13	Micro Pulse Length	10.4	microsec	5.13			
2.14	Micro Pulse Period	11.1	microsec	5.13			
3.0	1300 MHz Linac						
3.1	Average Gradient (ILC portion)	25	MV/meter				
3.2	Average Gradient (S-ILC portion)	23	MV/meter				
3.3	Average Beam Current	20	mA	1.2			
3.4	Pulse Length	1.25	msec	1.2			
3.5	Repetition rate	5	Hz	1.2			
3.6	1300 MHz Availability	88	%	1.6			
3.7	Initial Energy	420	MeV	2.6			
3.8	Length (approx.)	700	meters	3.1	3.13		
3.9	Peak RF Current	31.9	mA	3.3	3.15	3.17	3.18
3.10	Linac Species	H-		4.1			
3.11	Energy Variation (rms)	1	%	4.9			
3.12	Bunch Phase jitter (rms)	1	degree	4.9			
3.13	Final Energy	8	GeV	4.10			
3.14	Transverse Emittance (95% normalized)	2.5	π-mm-mrad	5.7	5.8		
3.15	Macro Bunch Duty Factor	67	%	5.10	5.12		
3.16	Macro Bunch Frequency	53	MHz	5.12			
3.17	Micro Pulse Length	10.4	microsec	5.13			
3.18	Micro Pulse Period	11.1	microsec	5.13			

Initial Configuration Parameters

http://pfdpro.fnal.gov/ICD/ICD%20Requirements.xls

4.0	Transfer Line					
4.1	Injection Stripping efficiency	98	%			
4.2	Length (approx.)	1000	meters			
4.3	Maximum Average activation level	20	mrem/hr			
4.4	Availability	98	%	1.6		
4.5	Momentum Aperture	+/- 0.75	%	3.11		
4.6	Minimum Transverse Aperture	25	π-mm-mrad	3.14	4.3	
4.7	Maximum Dipole Field	0.05	T	4.1	4.3	
4.8	Transfer Efficiency	99.99	%	4.3		
4.9	Final Energy Variation	+/- 0.11	%	5.10		
4.10	Energy	8	GeV	5.1		
5.0	Recycler					
5.1	Energy	8	GeV			
5.2	Storage Efficiency	99.5	%			
5.3	Average Recycler Beam Current	0.6	A	1.2	Not sure how this is defined....	
5.4	Availability	95	%	1.6		
5.5	Injection Rate	5	Hz	2.3		
5.6	Maximum Space Charge Tune Shift	0.05		5.2		
5.7	95% normalized transverse emittance	25	π-mm-mrad	5.6		
5.8	r.m.s. normalized transverse emittance	13	π-mm-mrad	5.6		
5.9	Bunching factor	2		5.6		
5.10	Longitudinal emittance per Bunch	0.5	eV-Sec	5.6	5.12	
5.11	Cycle Time	1.4	sec	6.1		
5.12	RF Frequency	53	MHz	6.2		
5.13	Abort Gap Length	700	nsec	6.3		
5.14	Peak Recycler Beam Current	2.36	A	6.5		
6.0	Main Injector					
6.1	120 GeV cycle Time	1.4	sec			
6.2	RF Frequency	53	MHz			
6.3	Abort Gap Length	700	nsec			
6.4	Acceleration Efficiency	99	%			
6.5	Main Injector Beam Current	2.36	A	1.1		
6.6	Final Energy	120	GeV	1.1		
6.7	120 GeV Beam Power	2.1	MW	1.1		
6.8	Availability	87	%	1.5		
6.9	Injection Energy	8	GeV	5.1		
6.10	Longitudinal emittance per Bunch	0.5	eV-Sec	6.2	6.11	
6.11	Space Charge Tune Shift	0.05		6.4		
6.12	95% normalized transverse emittance	25	π-mm-mrad	6.11		
6.13	r.m.s. normalized transverse emittance	13	π-mm-mrad	6.11		
6.14	Bunching factor	2		6.11		
7.0	8 GeV Extraction					
7.1	Fast Extraction Rate	15	Hz			
7.2	Fast Extraction Pulse Length	1.6	microsec			
7.3	Cycle Time	0.2	sec			

Facility Scope, Assumptions, and Interfaces

Facility Scope

- An 8 GeV superconducting linac
  - 325 MHz section to 420 MeV
  - 1.3 GHz section 420 MeV to 8 GeV
- Beamline for transport to the Recycler
- Modifications to Recycler for H- injection and transfer to MI
- Modifications to the Main Injector to support acceleration and extraction of high intensity beams

Assumptions

- Existing linac and booster no longer operational
- Existing Tevatron no longer operational (cryo systems available)
- Existing test beam facility in Meson continues at low duty factor
- Existing antiproton source reconfigured and operating in support of mu2e
- A neutrino beamline directed towards DUSEL operating

Interfaces

- DUSEL beamline: Main Injector extraction kicker
- mu2e : Recycler extraction kicker

Linac Layout

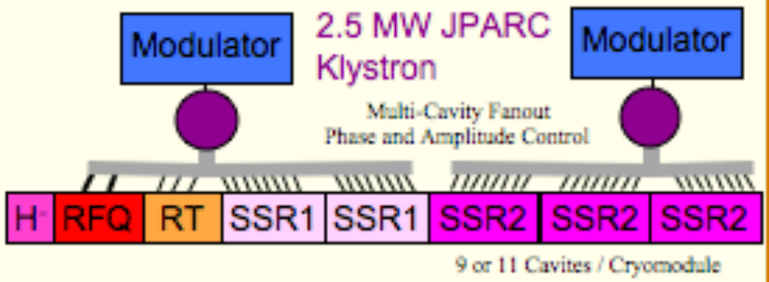
Project X
1000 kW 8GeV Linac

28 Klystrons (2 types)
461 SC Cavities
58 Cryomodules

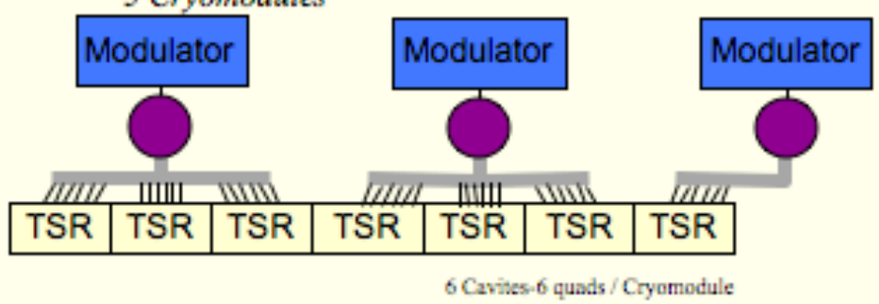
Front End Linac

325 MHz 0-10 MeV
1 Klystron (JPARC 2.5 MW)
16 RT Cavities

325 MHz 10-120 MeV
1 Klystron (JPARC 2.5 MW)
51 Single Spoke Resonators
5 Cryomodules



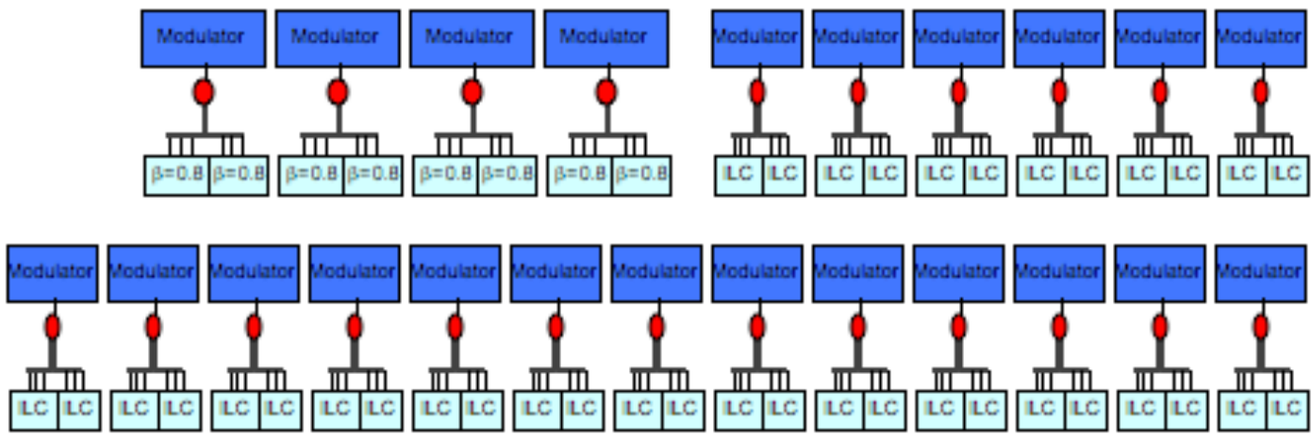
325 MHz 0.12-0.42 GeV
3 Klystrons (JPARC 2.5 MW)
42 Triple Spoke Resonators
7 Cryomodules



1300 MHz LINAC

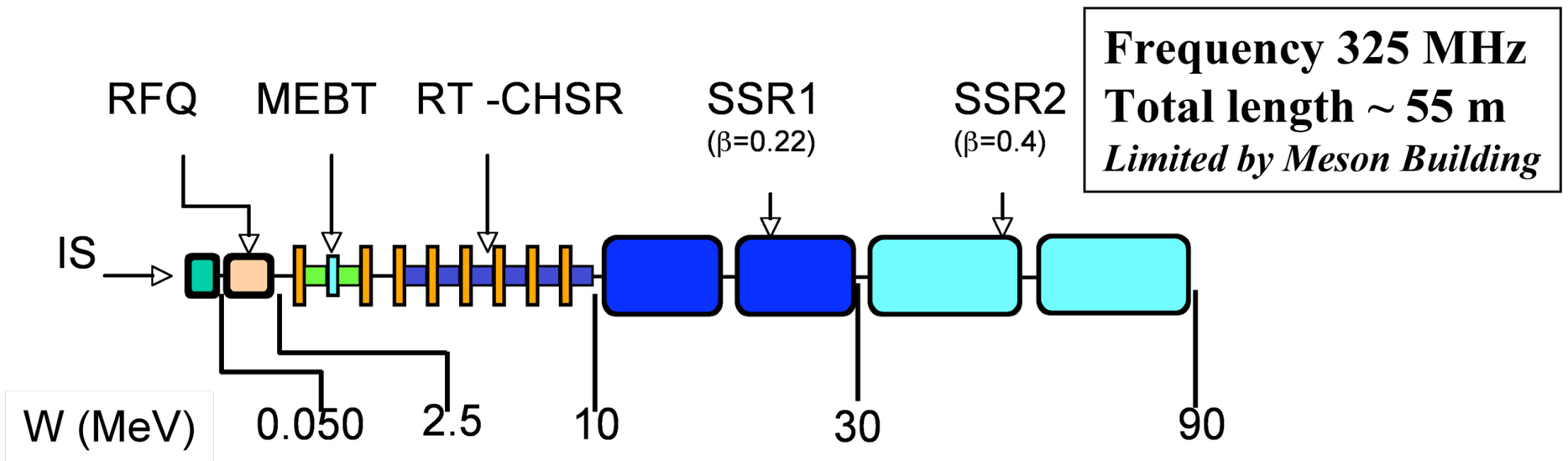
1300 MHz 0.42-1.3 GeV
4 Klystrons (ILC 10 MW MBK)
64 Squeezed Cavities (β=0.81)
8 Cryomodules

1300 MHz 1.3-8.0 GeV
19 Klystrons (ILC 10 MW MBK)
304 ILC-identical Cavities
38 ILC-like Cryomodules

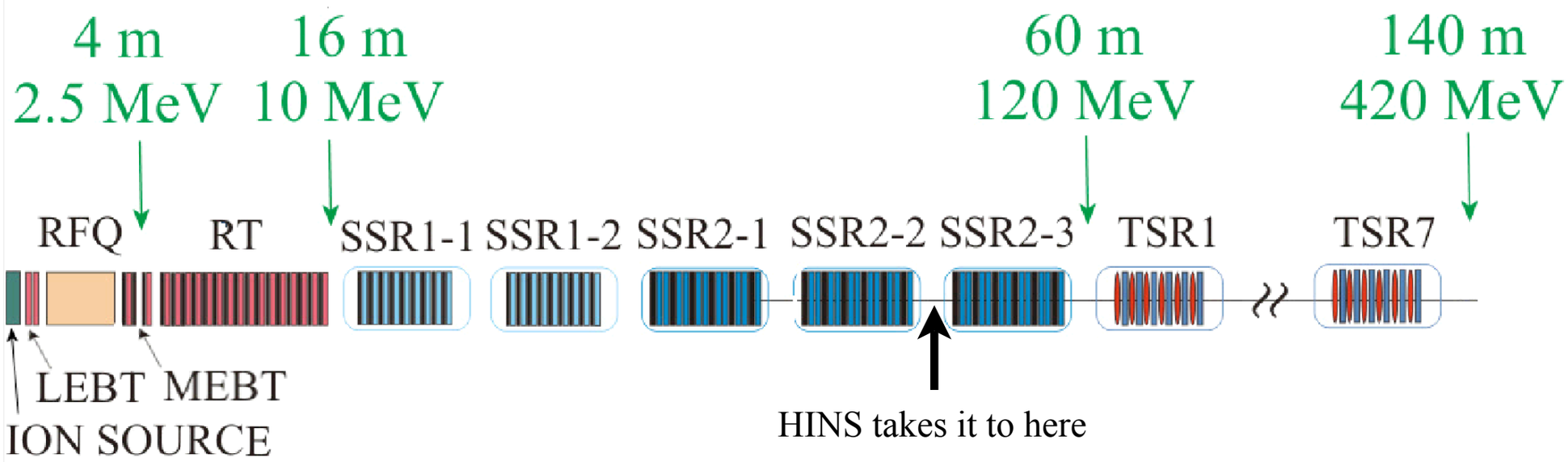


325 MHz Linac

- builds off the HINS project:
  - "to address accelerator physics and technology questions for a new concept, low-energy, high intensity, long pulse H^- superconducting linac"
    - Demonstrate beam acceleration using superconducting spoke type cavity structures starting at a beam energy of 10 MeV
    - Demonstrate the use of high power RF vector modulators to control multiple RF cavities driven by a single high power klystron for acceleration of a non-relativistic beam
    - Demonstrate beam halo and emittance growth control by the use of solenoid focussing optics up to 60 MeV
    - Demonstrate fast, 325 MHz bunch-by-bunch, beam chopper



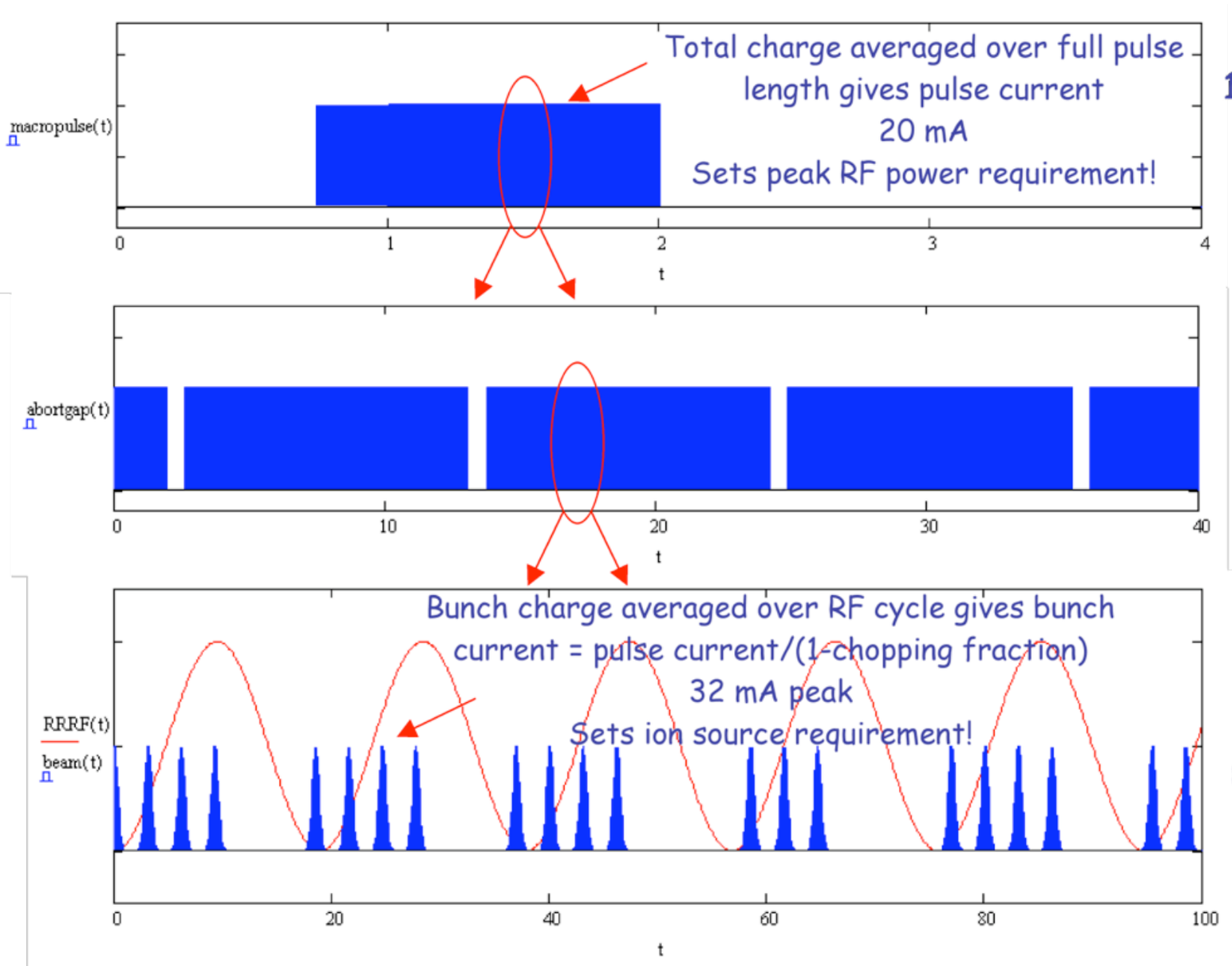
325 MHz Linac



- 50 keV H^- ion source
- 2.5 MeV RFQ
- Medium energy beam transport
  - 2 rebuncher RF cavities
  - 3 solenoids
  - beam chopper
- Room temperature cavities interspersed with SC solenoids to 10 MeV
- β=0.22 single-spoke resonator SC cavities to 30 MeV
- β=0.4 single-spoke resonator SC cavities to 120 MeV
- β=0.6 triple-spoke resonator SC cavities to 420 MeV
- Vector modulators throughout … multiple cavities per klystron … technical risk …

325 MHz Linac Beam structure

- Beam chopper has to match:
  - 53 MHz structure for the Recycler/Main Injector
  - 700 nsec gap every 11.1 μsec for the Recycler / Main Injector kickers



1.25 msec Linac beam pulse
4 msec full scale

Linac beam chopped for
700 nsec RR Abort Gap
40 μsec full scale

Linac 325 MHz beam
chopped for RR RF
multiple linac bunches per
53 MHz RR RF cycle
100 nsec full scale

Linac Layout

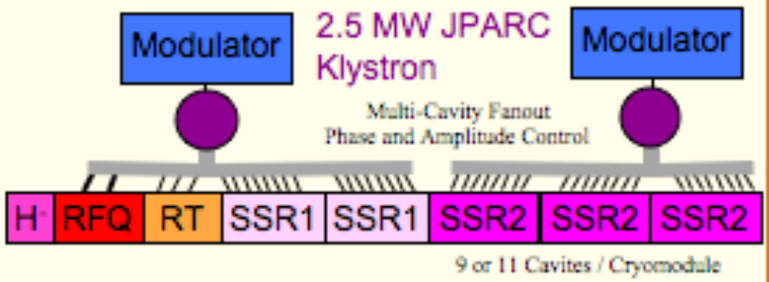
Project X
1000 kW 8GeV Linac

28 Klystrons (2 types)
461 SC Cavities
58 Cryomodules

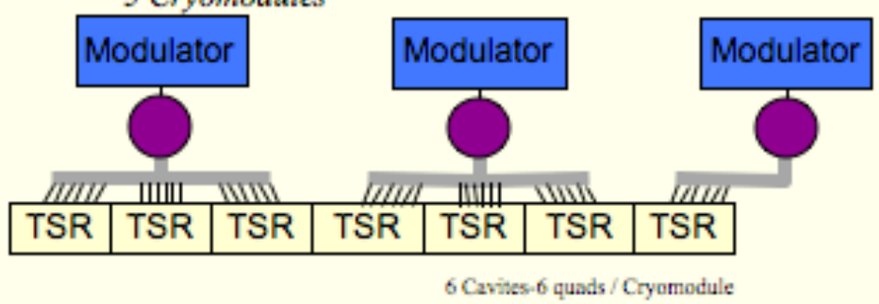
Front End Linac

325 MHz 0-10 MeV
1 Klystron (JPARC 2.5 MW)
16 RT Cavities

325 MHz 10-120 MeV
1 Klystron (JPARC 2.5 MW)
51 Single Spoke Resonators
5 Cryomodules



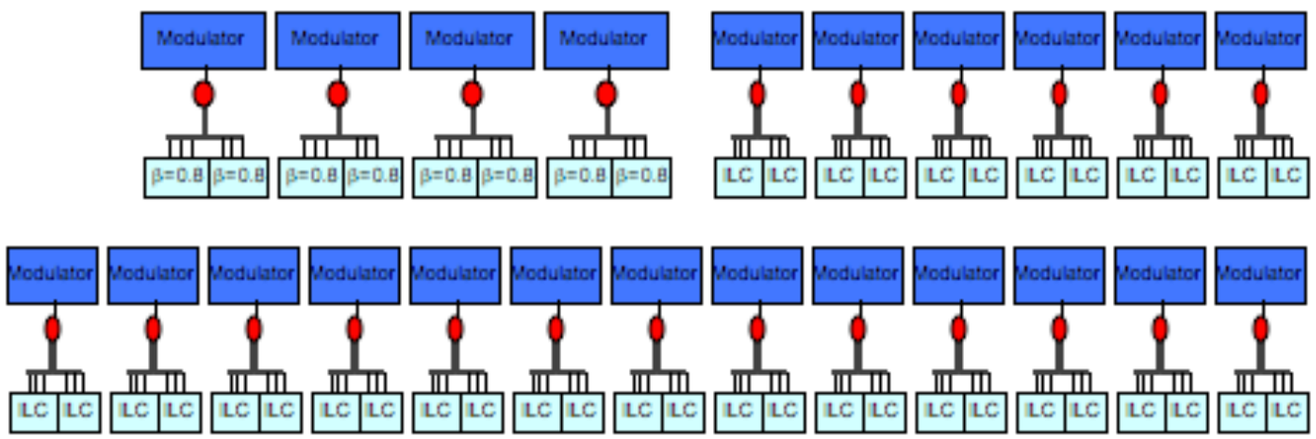
325 MHz 0.12-0.42 GeV
3 Klystrons (JPARC 2.5 MW)
42 Triple Spoke Resonators
7 Cryomodules



1300 MHz LINAC

1300 MHz 0.42-1.3 GeV
4 Klystrons (ILC 10 MW MBK)
64 Squeezed Cavities (β=0.81)
8 Cryomodules

1300 MHz 1.3-8.0 GeV
19 Klystrons (ILC 10 MW MBK)
304 ILC-identical Cavities
38 ILC-like Cryomodules



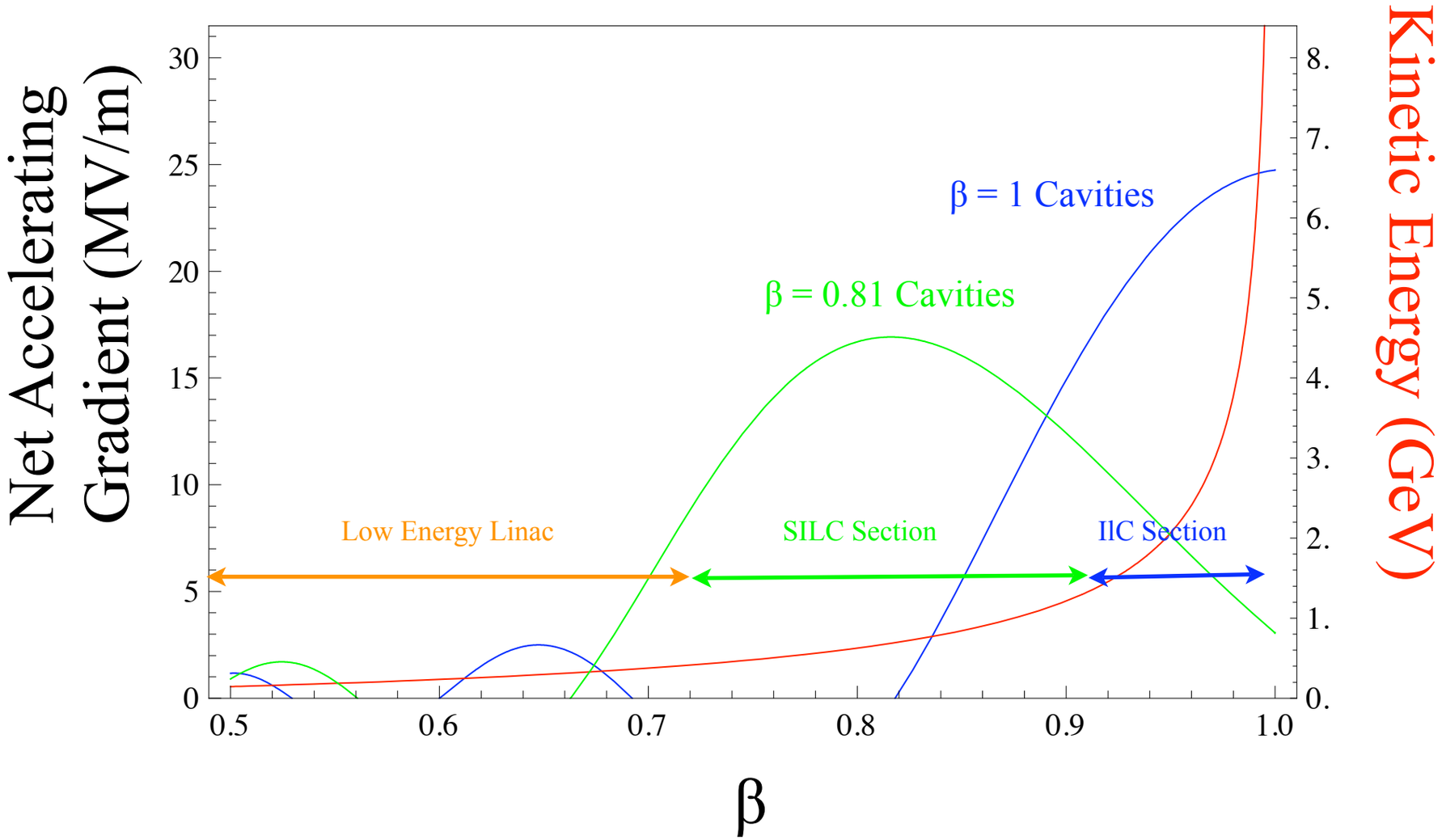
- Use S-ILC for β=0.81 section: 0.42 - 1.3 GeV
  - squeezed ILC cavity -- same frequency but shorter cavity length
  - needs to be developed for Project X

- Use ILC Type 4 Cryomodules as prototype for β=1 section
  - use same cryomodule everywhere
  - 8 Cavities, 1 quad in all cryomodules
  - 25 MV/m
  - CMs are interchangeable - 1 type of spare in β=1 section
  - 2 CM/klystron (instead of 3)
  - instead of ILC-1 (7 cavities, 2 quads) and ILC (8 cavities, 1 quad)
  - stand alone quads in regions where more focussing is needed (short cryo module without cavities)
- Warm sections ~4 CMs (cryo junction boxes)

- Vector modulators throughout … multiple cavities per klystron .. technical risk …

Cavity response vs β

- as particle velocity changes and it is a fixed frequency cavity, the energy gain through the cavity is different -- different cavity designs



Transfer line

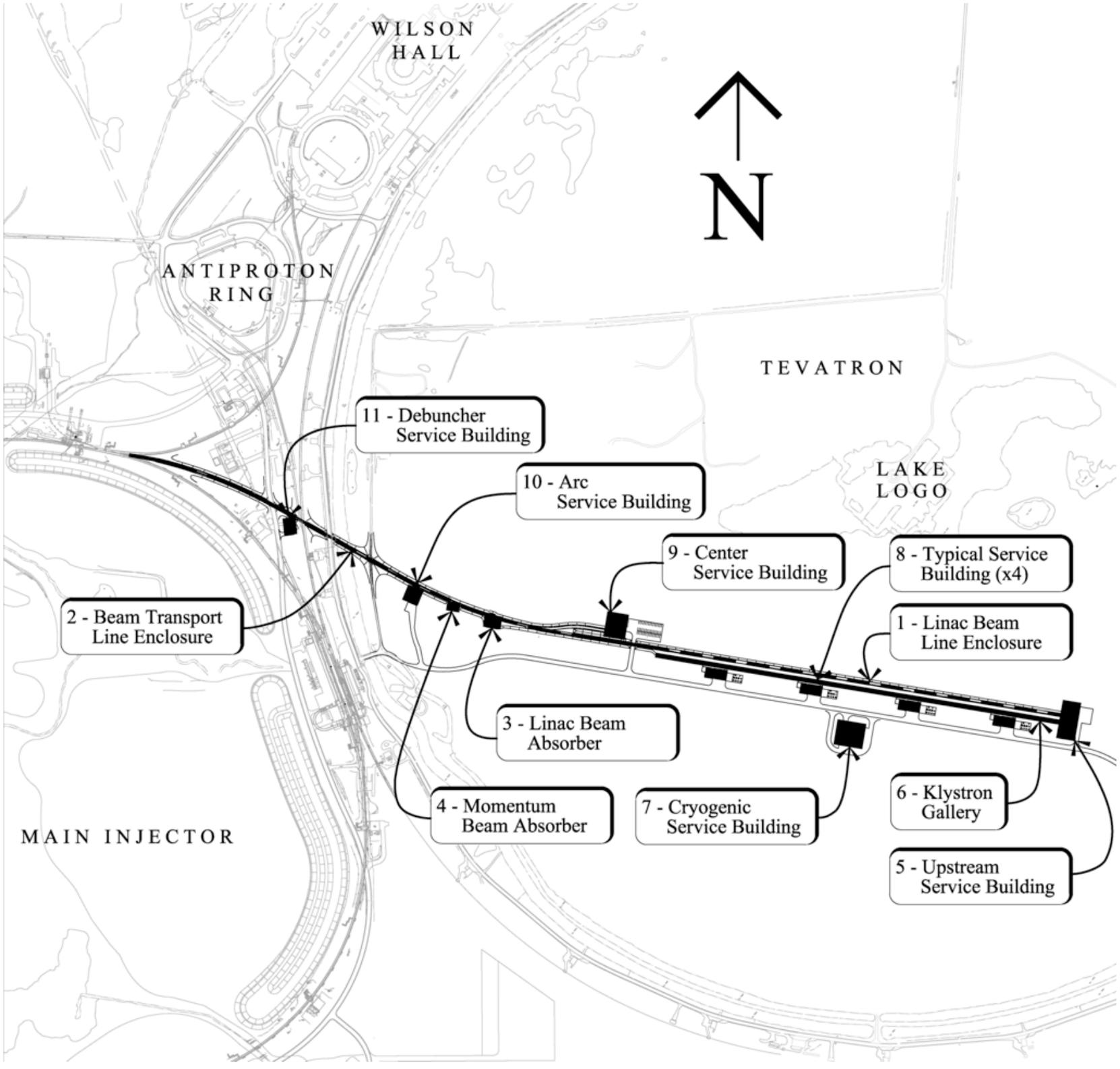
- from the output of the linac to the MI tunnel
  - ~1 km long
  - <500 G fields -- mitigate magnetic stripping of the H^- electrons
  - liquid nitrogen cryogenic shield -- mitigate blackbody stripping of the H^- electrons

- Acceptance matched to Recycler
  - 25 π mm mr
  - ±0.75% momentum aperture
  - transverse collimation to capture large amplitude particles
  - momentum collimation to capture off momentum particles
  - passive phase rotator cavity to compensate for energy jitter

- Permanent magnets at 8 GeV (possible use of Main Ring or PEP-II HER magnets being investigated)

- losses less than <1 W/m ⇒ >99.9% transmission efficiency

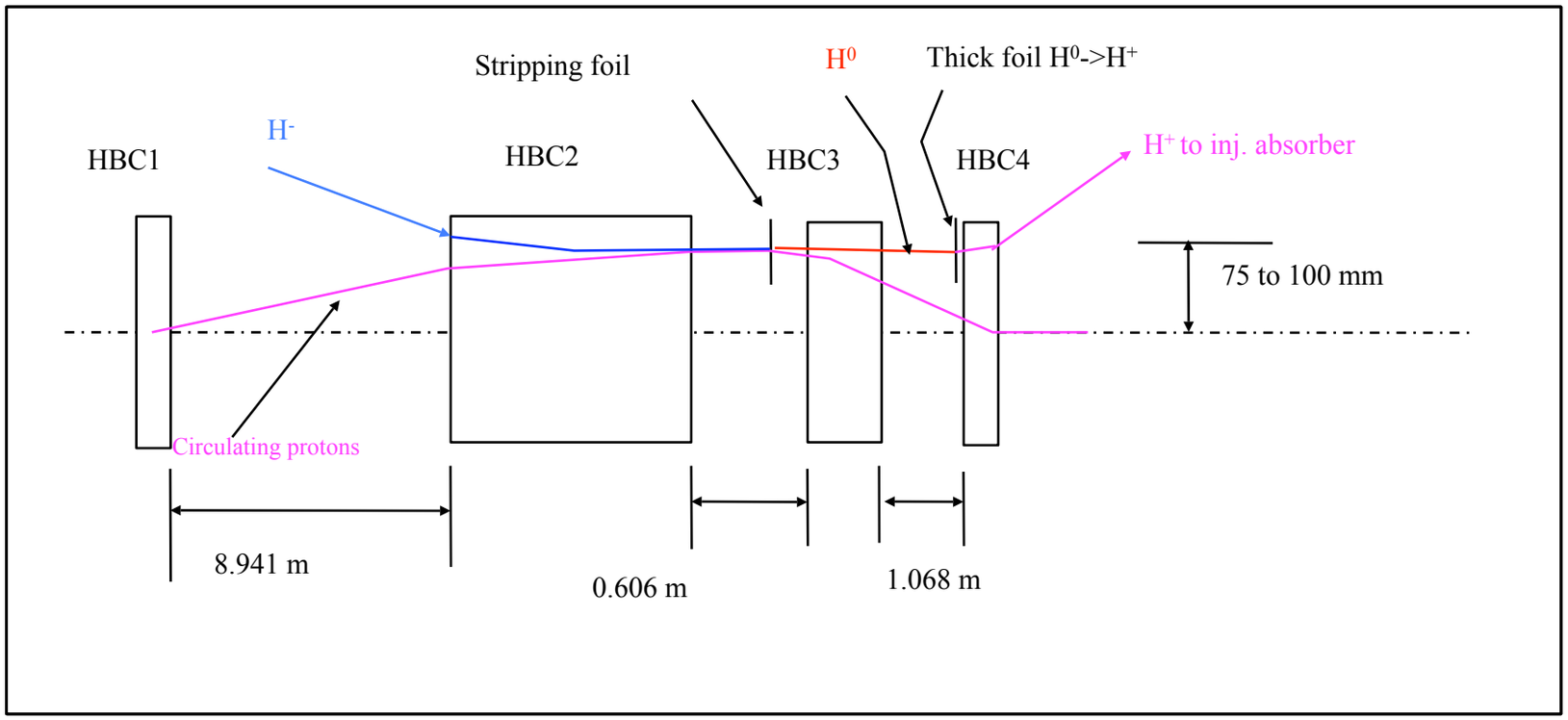
Site Layout


WILSON
HALL
N
ANTIPROTON
RING
TEVATRON
LAKE
LOGO
11 - Debuncher
Service Building
10 - Arc
Service Building
9 - Center
Service Building
8 - Typical Service
Building (x4)
2 - Beam Transport
Line Enclosure
1 - Linac Beam
Line Enclosure
3 - Linac Beam
Absorber
4 - Momentum
Beam Absorber
7 - Cryogenic
Service Building
6 - Klystron
Gallery
5 - Upstream
Service Building
MAIN INJECTOR

Injection System

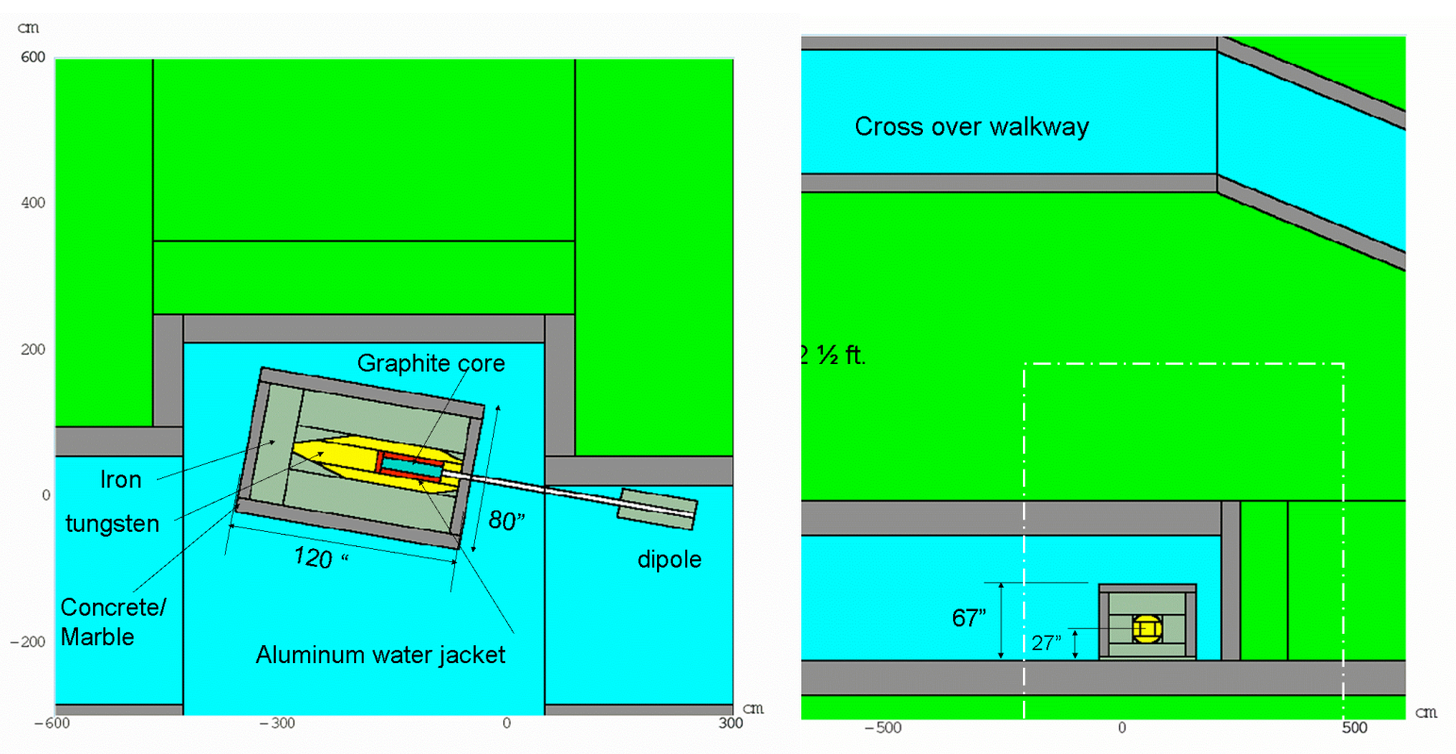
- Multi turn Stripping System
  - 1.25 msec = 110 turns in Recycler
  - thin foil injection

- Transverse / Longitudinal painting ⇒ Kapchinskiy - Vladimirskiy distribution
  - ellipsoidal beam distribution that leads to a linear space charge force within beam radius
  - RMS envelope radius = $^1/_2$ beam radius
  - minimize space charge tune shift in the Recycler and Main Injector



Injection System

- elevation throughout matched to Main Injector elevation
  - adequate shielding
  - interferences with existing enclosures (TeV and AP1)
  - makes the line longer ⇒ vertical bend to reach Recycler elevation
- Beam absorber to catch H^- and H^0
  - 2% stripping inefficiency ⇒ 20 kW
  - design for 100kW
  - designed around MI tunnel



Recycler

- Modified for NOvA by this time
  - proton ring with single turn transfer to MI
- Modifications to lattice for injection system
  - remove injection from MI 8 line!
- Add flexibility to lattice to handle tune shift, operating point, etc.
  - expect 1.6e14 with KV distribution to give 0.05 tune shift
- 53 MHz RF to capture injected beam
  - make identical to MI system
- Fast extraction (1.6 μsec length) for μ2e
  - move NOvA injection kicker and supplies
- Electron cloud mitigation
  - coat the beam pipe?

Main Injector

- Single turn injection from Recycler
- ~3x intensity of NOvA era
- Upgrade RF system:
  - need more bucket area for acceleration
  - second harmonic RF also needed
  - 53 MHz design exists, 2nd harmonic does not
- Electron Cloud mitigation
  - TiN coating to decrease secondary emission yield
- First order matched γ_T jump
  - 8 pulsed quad triplets
  - 2 units in 0.5 msec (16x faster than normal ramp)

Cavity Characteristics

Q 4000

R_{sh} 100 kΩ

R/Q 25 Ω

f_0 52.9577 MHz

Range ±150 kHz

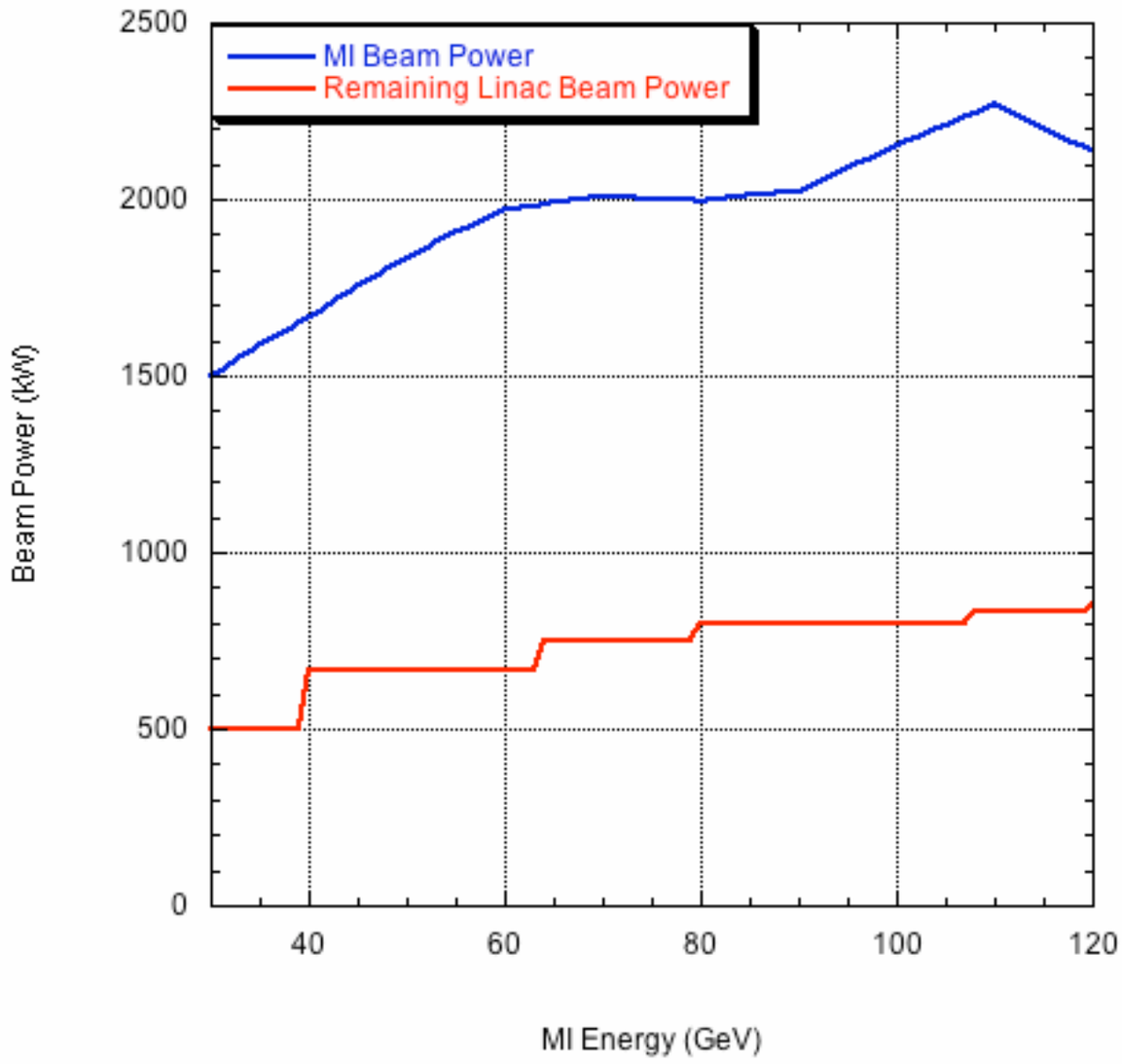
Material Cu coated stainless

Voltage 300 kV

Proton Driver design, Mar 2005

Main Injector Beam Power

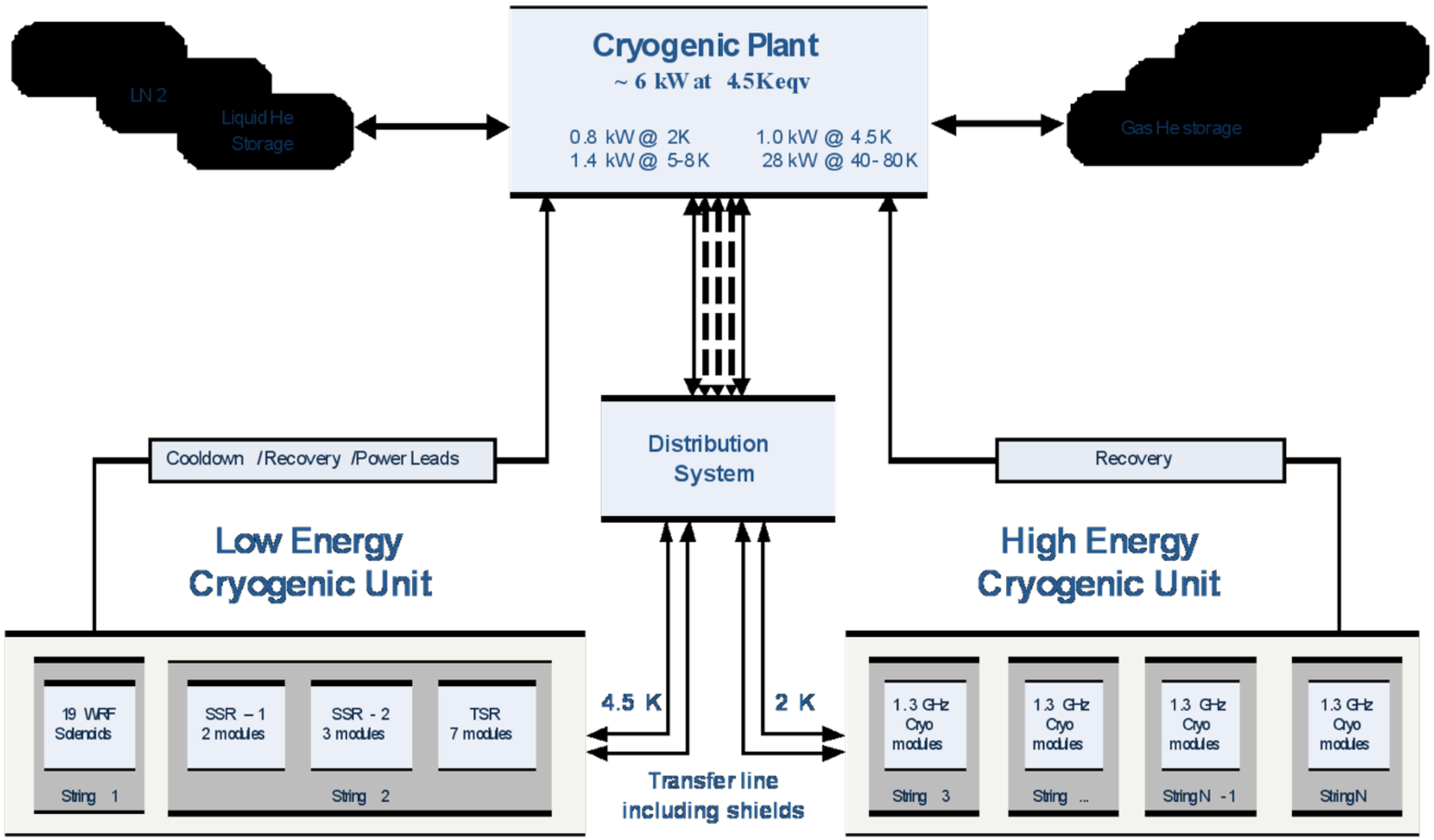
- Optimum Energy for long baseline neutrino program?
  - ➢ deliver > 2 MW for extracted beam energies > 60 GeV (1.8 MW at 50 GeV)
    - varying the MI cycle time
    - holding beam in Recycler to match 5 Hz from linac with varying MI cycle time
  - ➢ deliver > 500 kW for 8 GeV beam



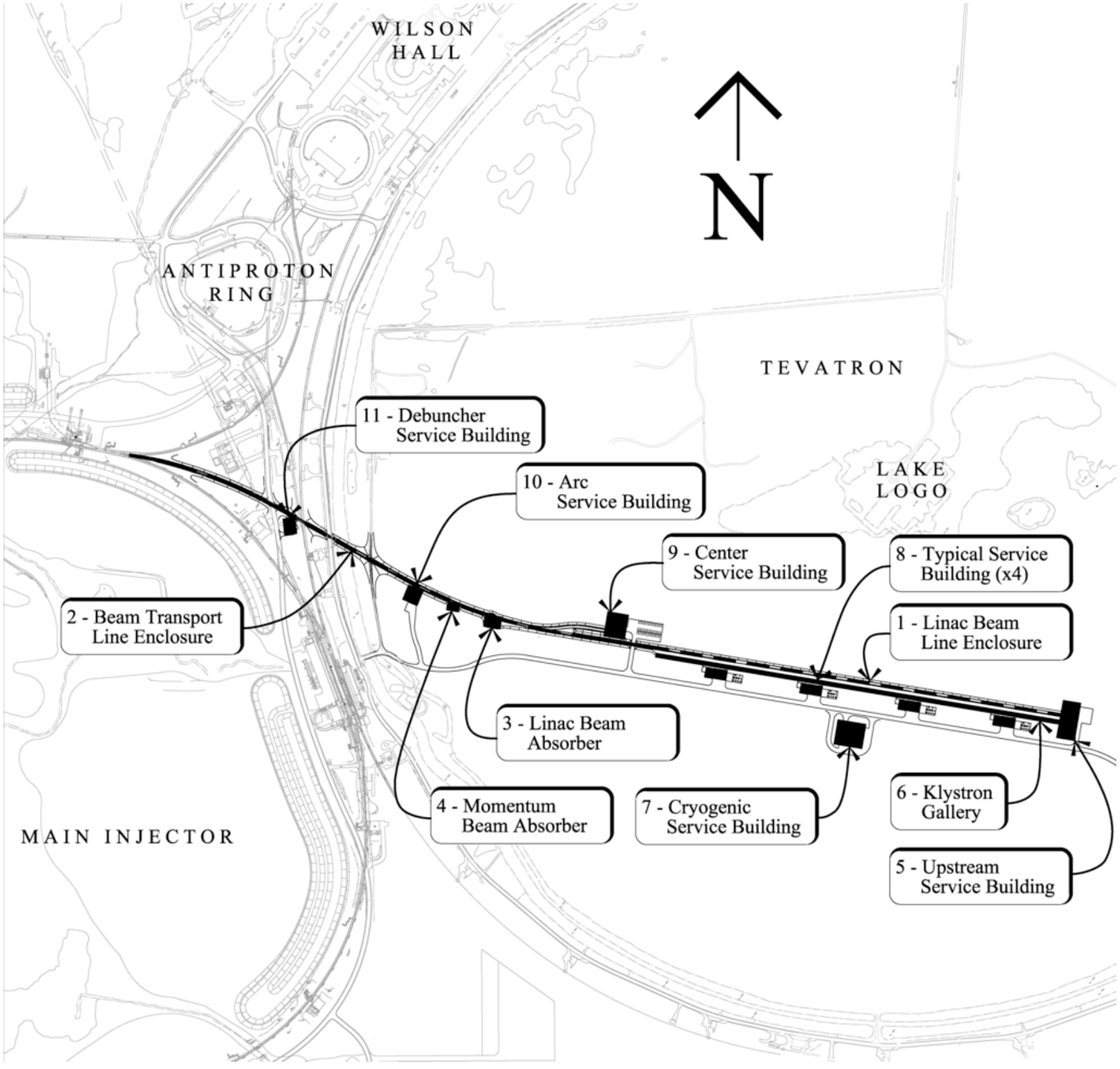
Cryogenics

- New Cryo plant
  - 325 MHz linac: two phase liquid helium at 4.5 K
  - 1.3 GHz linac: saturated He II at 2 K

- Re use Tev ancillary components



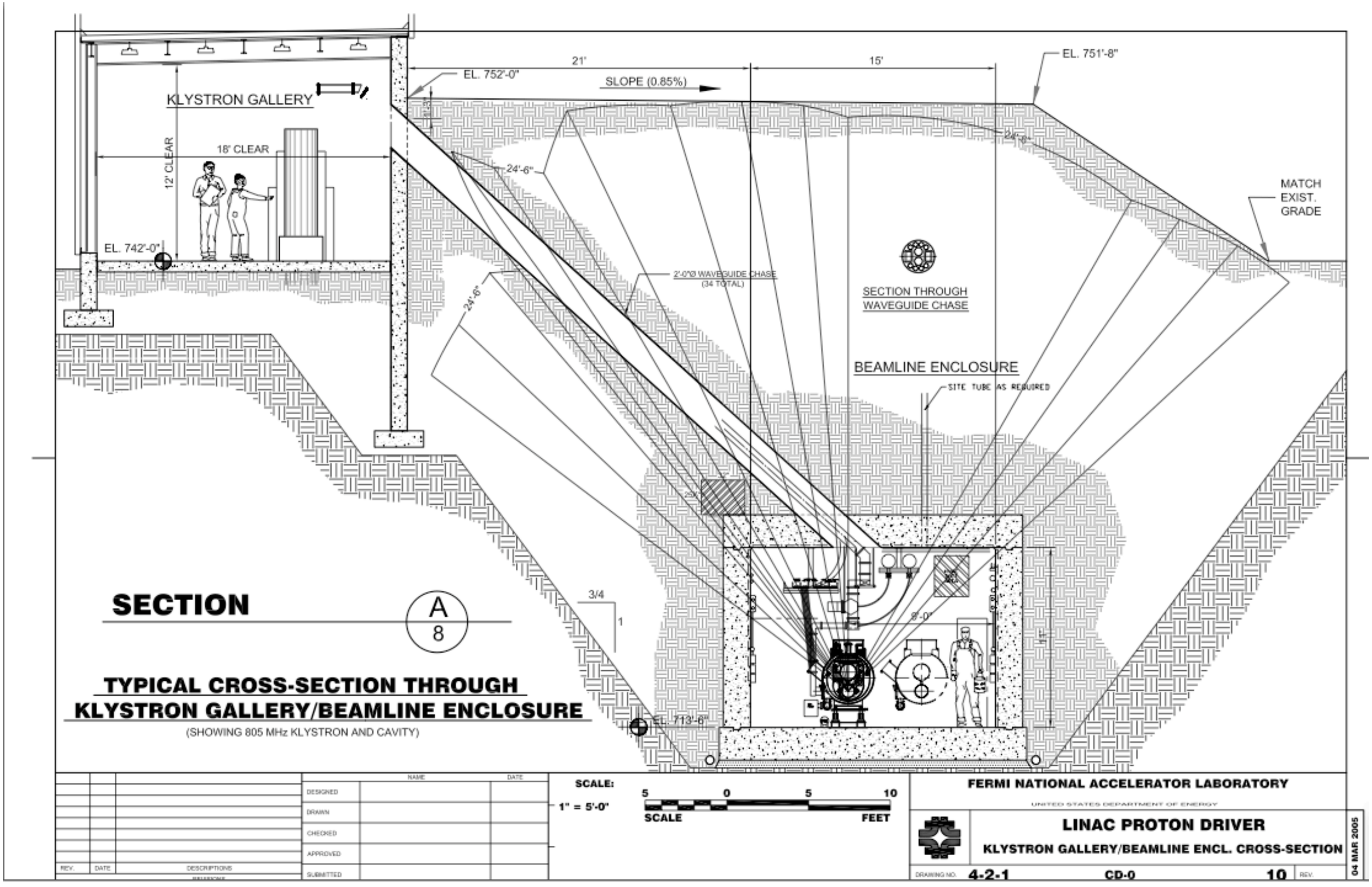
Site Layout - Conventional Facilities



Conventional Facilities

- 4 below grade construction:
  - Linac enclosure
  - Transfer line enclosure
  - Linac dump
  - Momentum dump (injection dump is in MI tunnel)
- 7 above grade construction:
  - Upstream service building (ion source)
  - Klystron gallery
  - Cryo service building (plant)
  - 4 additional service buildings
- Site Prep:
  - Drainage
  - Roads
  - Landscaping
  - Wetlands mitigation (60 acres)
    - 3:1 for creation ($50k/acre)
    - buy credits offsite?
  - Space Replacement
    - 150000 square feet
- Utilities
  - Power
  - Communications
  - Water

Cross Section of Linac Tunnel



Instrumentation & Controls

- Beam loss monitoring
- Beam Position monitoring
- Machine protection system

- develop new instrumentation
  - ➢ especially in SCRF sections

- Time Stamping
- 1 M devices and properties
- Machine protection system

- Evolving System
  - ➢ through NOvA era
  - ➢ support of HINS and NML efforts

  - ➢ Mix of EPICS and ACNET

Schedule

- Collaboration Meeting: 21-22 November

  http://projectx.fnal.gov

- Research Design & Development Plan
  - ➢ to carry from CD-0 ("Approve Mission Need") to CD-2 ("Approve Performance baseline")
- Jim Kerby putting together a cost estimate for CD-0, working off the ICD

- CD-0
  - ➢ DoE writes the document, not us
  - ➢ not a technology choice
    - " The mission need is independent of a particular solution, and should not be defined by equipment, facility, technological solution, or physical end-item"
  - ➢ present a cost range (0.5x - 2x)
    - cost estimate? is this a "Major System Project"? >750 M$?
    - changes review process and who has critical decision authority (e.g., the Secretarial Acquisition Executive or the Under Secretary)
  - ➢ Director's Review in February 09
  - ➢ Department of Energy Review in Spring 09

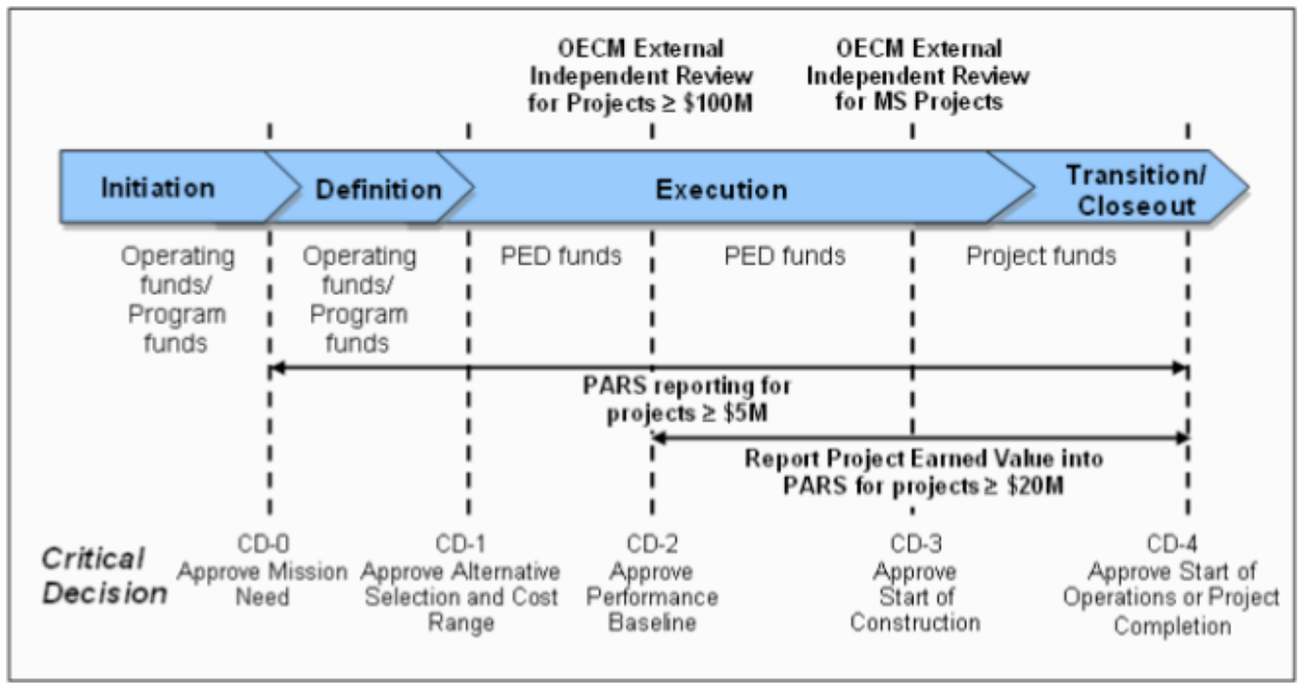
my 2¢

- DoE seems to be behind Steering Group plan for Project X
  - A plan for an 8 GeV superconducting linac

- CD-0 is "Approve Mission Need"
  - "A Mission Need Statement is the translation of this gap into functional requirements that cannot be met through other than material means. It should describe the general parameters of the project, how it fits within the mission of the Program, and why it is critical to the overall accomplishment of the Department mission, including the benefits to be realized."

  - between CD-0 and CD-1 it is up to us to investigate alternatives
    - because we need some documents for this review
  - CD-1 ("Approve Alternative Selection and Cost Range")
    - "CD-1 approval marks the completion of the project Definition Phase, during which time the conceptual design is developed. This is an iterative process to define, analyze, and refine project concepts and alternatives. This process uses a systems methodology that integrates requirements analysis, risk identification and analysis, acquisition strategies, and concept exploration to evolve a cost-effective, preferred solution to meet a mission need."
    - Conceptual Design Report
    - Design Review of the Conceptual Design
    - and a whole bunch more Project Management (16 separate documents and plans)

- the definition phase
  - "Upon approval of mission need, the project enters the Definition Phase where alternative concepts, based on user requirements, risks, costs, and other constraints, are analyzed to arrive at a recommended alternative. This is accomplished using Systems Engineering and other techniques and tools such as alternatives analysis and Value Management/Value Engineering. This ensures the recommended alternative provides the essential functions and capability at optimum life cycle cost, consistent with required performance, scope, schedule, cost, security, and Environment, Safety and Health considerations. During this phase, the required Value Management assessment is completed, and more detailed planning is accomplished which further defines required capabilities. The products produced by this planning provide the detail necessary to develop a range of estimates for the project cost and schedule."



Summary

- Developed an Initial Configuration Document to provide
  - >2 MW at 120 GeV
  - additional 8 GeV beam for other experiments
  - upgrade path to higher beam power
    - double the repetition rate (5 Hz ⇒ 10 Hz)
    - double the pulse length (1.25 msec ⇒ 2.5 msec)
    - conventional facilities, cryo plant, and utilities designed to accomodate these upgrades
  - 325 MHz and 1300 MHz superconducting rf linac
  - multi-turn injection to Recycler
  - Single turn transfer to Main Injector

- Available tomorrow in http://projectx-docdb.fnal.gov